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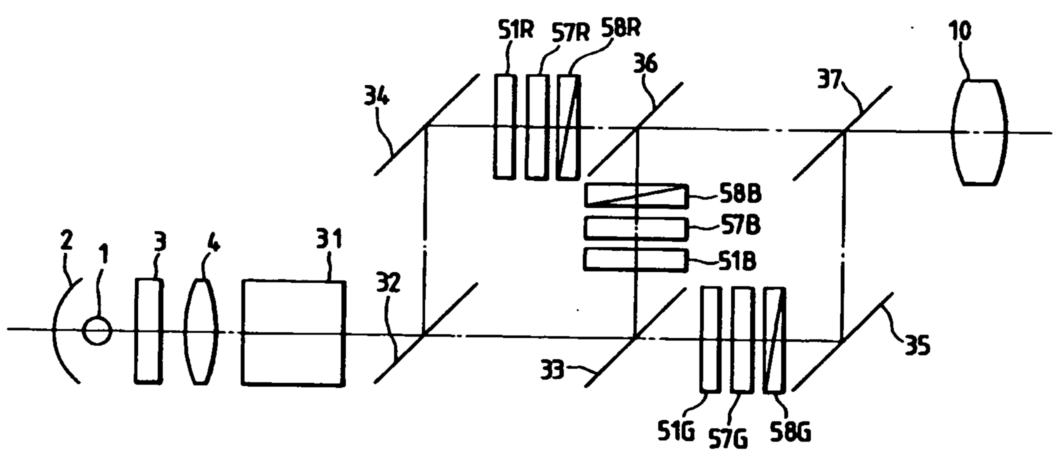
(54) **projector.**

(57) In a projector, wherein the polarized states of a plurality of color lights illuminating image forming means (57R,57B,57G) differ from the polarized states of image lights projected onto a projection surface and the image lights of respective colors projected onto the projection surface have a common polarized state, means (51R,51B,51G) for varying the polarized state is disposed in the optical path of each of the color lights.

FIG. 5



BACKGROUND OF THE INVENTION

Fi ld of the Inv ntion

This invention relates to a projector.

R lated Background Art

A liquid crystal light value as the image forming means of a projector is often of the twist nematic type (hereinafter referred to as the TN type. This TN type liquid crystal, as is well known, is great in field angle characteristic and considerably differs in contrast depending on the direction in which it is seen (see Appl. Phys. Lett. 38 (1981), 497). Therefore, in a direct view liquid crystal display device wherein a liquid crystal light value is directly observed, the directions of liquid crystal molecules, a polarizer and an analyzer are adjusted in accordance with this characteristic.

Referring to Figures 1A and 1B of the accompanying drawings which shows this situation, the visual angle 44 of the observer 42 is inclined by an angle θ with respect to the normal 43 to a direct vi w liquid crystal display device 41 shown in Figure 1A, and usually the area around this visual angle θ is the view field area. Accordingly, in order to adjust the field angle characteristic of the TN type liquid crystal to this area, use is made of a construction as shown in Figure 1B wherein the dir ctions of transmission polarization of a polarizer 45 and an analyzer 49 and the directions of orientation 46 and 48 of liquid crystal molecules 47 at th opposite ends of the liquid crystal layer thereof are inclined by 45° with respect to a horizontal axis.

In a projector, the angular expanse of a light beam incident on liquid crystal is smaller than in the direct view type, and also for an improvement in the quality of image (particularly contrast), a similar construction is often used and there is also obtained a secondary effect such as a reduction in cost by production facilities being made common.

Also, in recent years, various polarizing illumination devices for converting indefinite polarized light from a light source into linearly polarized light having a particular direction of polarization have been proposed as means for enhancing the luminance of a projector and increasing the efficiency of light utilization of the projector, but for the r ason set forth above, the linearly polarized light mitted from those polarizing illumination devices must have its direction of polarization inclined by 45° with respect to said horizontal axis.

As a method of inclining th direction of polarization of linearly polarized light emitted from a polarizing illumination d vice, there ar conceived polarizing conversion systems as shown, for exampl , in Figures 2 and 3 of th accompanying drawings. In Figur 2 which shows only the ess ntial portions of a polarizing illumination devic describ d in Japan s Laid-Open Pat nt Application No. 61-90584, indefinite polarized light from a light source (not shown) is divided into two linearly polarized components S and P by the multi-layer film 1001 of a polarizing beam splitter, and the polarized component S is bent in the same direction of travel as the polarized component P by the total reflection surface 1002 of a rectangular prism, whereafter it has its direction of polarization rotated in the same direction of polarization as the polarized component P by a half wavelength optical phase plate 1003a. The two light beams which have been made to have the same direction of travel and the same direction of polarization in this manner are caused to enter a half wavelength optical phase plate 1003b, whereby the directions of polarization of the two light beams can be inclined in a direction depending on the optical axis of the half wavelength optical phase plate 1003b.

Figure 3 shows an example in which quarter wavelength optical phase plates are used instead of half wavelength optical phase plates. This example is the same as the example shown in Figure 2 in that the polarized component S is bent in the same direction of travel as the polarized component P by the total reflection surface of the rectangular prism 1002, but a quarter wavelength optical phase plate 1112a is disposed on the optical paths of two light beams so that said two light beams may become circularly polarized lights and further, a quarter wavelength optical phase plate 1112b is disposed so that said two circularly polarized light beams may become linearly polarized lights.

Figure 4 of the accompanying drawings schematically shows a construction in which the polarizing illumination device shown in Figure 2 or 3 is applied to a color projector. The reference numeral 31 designates a polarizing element shown in Figure 2. White linearly polarized light emitted from the polarizing element 31 is resolved into three colors, red, green and blue, by a dichroic mirror 32 reflecting red and transmitting green and blue therethrough, a dichroic mirror 33 reflecting blue and transmitting green therethrough and a total reflection mirror 34, and the respective lights are transmitted through liquid crystal light valves 7R, 7G, 7B and polarizing plates 8R, 8G, 8B, and thereafter are again synthesized by a total reflection mirror 35, a dichroic mirror 36 reflecting blue and transmitting red therethrough and a dichroic mirror 37 reflecting green and transmitting red and blu th r through.

Th synthesized light is projected onto a screen, n t shown, by a projection l ns 10.

Accordingly, in this color projector, not only th efficiency of light utilization can be increased, but

also th direction of polarization of the polarized illuminating light can be adjusted to the direction of ori ntation of liquid crystal molecul s.

The system shown in Figur 4, how v r, suffers from the following problems. The optical phase plate exhibits wavelength dependency and therefore, when an attempt is made to change the direction of polarization of light of a wide band like white light into a certain state, if for example, the optical phase plate is designed for the wavelength of the G component of white light, it will become impossible to shift the phase by the same amount as for the G component, for the B and R components having wavelengths differing from the wavelength of the G component. Accordingly, almost all part of the G component has its direction of polarization set to a predetermined state, while considerable parts of the B and R components have their directions of polarization not set to this state.

The polarizing conversion system is a system for supplying light having a particular direction of polarization and thus, light which does not have this direction of polarization is not utilized.
Accordingly, considerable parts of the B and R components are losed due to the wavelength dependency of the optical phase plate and moreover, the light from the projector becomes greenish. Also, for a similar reason, considerable parts of the G and R components will be losed if the optical phase plate is designed for the wavelength of the B component of white light, and considerable parts of the B and G components will be losed if the optical phase plate is designed for the wavelength of the R component of white light.

SUMMARY OF THE INVENTION

The present invention had been made in order to solve the above-noted problems, and provides a projector in which the polarized states of a plurality of color lights illuminating image forming means differ from the polarized states of image lights projected onto a projection surface and the image lights of respective colors projected onto said proj ction surface have a common polarized state, characterized in that means for varying the polarized state is disposed in the optical path of each of the color lights.

The present invention also provides a projector having image forming means for forming a plurality of color images, illuminating means for illuminating said image forming means with each color light, and projection means for projecting each of th color images, characterized in that optical m ans for turning the direction of polarization by about 45° is disposed in the optical path of said ach color light.

BRIEF DESCRIPTION OF THE DRAWINGS

Figures 1A and 1B ar illustrations f a dir ct vi w liquid crystal display d vic .

Figure 2 is a schematic view of a projection display device according to the prior art.

Figure 3 is a schematic view of a projection display device according to the prior art.

Figure 4 is a schematic view of a color projection display device according to the prior art.

Figure 5 schematically shows the consturction of a projection display device according to an embodiment of the present invention.

Figure 6 illustrates the actions of the essential portions of the Figure 5 embodiment.

Figure 7 schematically shows a projection display device according to another embodiment of the present invention.

Figure 8 shows the construction of the essential portions of another embodiment.

Figure 9 illustrates the actions of the essential portions of the Figure 8 embodiment.

Figure 10 illustrates the actions of the essential portions of the Figure 8 embodiment.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Figure 5 schematically shows the consturction of a color image projector according to an embodiment of the present invention. The portions of this projector which are common to those of the prior-art examples are given the same reference numerals. The polarizing element 31 corresponds to the portion excluding the half wavelength optical phase plate 1003b in Figure 2. Light from a light source 1 enters a condenser lens 4 via a reflecting mirror 2 and a heat cut filter 3. A parallel light beam emergent from the condenser lens 4 is converted by the polarizing element 31 into linearly polarized light (P-polarized light) which, in this case, is perpendicular to the direction of travel and polarized in a direction in the plane of the drawing sheet of Figure 5. White linearly polarized light emergent from the polarizing element 31 is resolved into three colors, red, green and blue, by a dichroic mirror 32 reflecting red and transmitting green and blue therethrough, a dichroic mirror 33 reflecting blue and transmitting green therethrough and a total reflection mirror 34, and the respective color lights are converted by half wavelength optical phase plates 51R, 51G and 51B into linearly polarized lights having their directions of polarization inclined by 45° with respect to the plan f the drawing sheet of Figur 5, wh reafter th y pass through liquid crystal light values 57R, 57G and 57B having th ir molecul ori ntation ax s inclined by 45° with respect to the plan of th drawing

sh t of Figur 5, and further pass through polarizing plates 58R, 58G and 58B. Taking the red color as an xample, th action th reof will h r inafter be d scribed with r f r nce to Figur 6.

Incident light comprising linearly polarized light E1 parallel to the horizontal axis passes through a half wavelength optical phase plate 51R having its optical axis 52 inclined by 22.5° and has its direction of polarization rotated by 45° (E2), whereafter it is modulated in conformity with an image signal by the liquid crystal light value 57R comprising a liquid crystal construction shown in Figure 1B, and passes through the polarizing plate 58R acting as an analyzer. The half wavelength optical phase plate 51R is selected such that in the wavelength range of the red light (generally 600 - 700 nm), retardation becomes approximate to the half wavelength.

This also holds true of the green light and the blue light.

The respective color lights modulated by cor r sponding liquid crystal light valves are again synthesized by a total reflection mirror 35, a dichroic mirror 36 reflecting blue and transmitting red therethrough and a dichroic mirror 37 reflecting green and transmitting red and blue therethrough. The synthesized light is projected onto a screen, not shown, by a projection lens 10.

In the present embodiment, the white light is first divided into red and green and blue components, and thereafter is divided into blue and green, wh reas the order of the color resolution and color synthesis is not restricted to the present construction. Also, in the construction shown in Figure 5, half wavelength optical phase plates are provided for red, green and blue, respectively, but a half wavelength optical phase plate common to green and blue may be provided between the dichroic mirrors 32 and 33. However, as for the blue light, th wavelength dependency of the difference in r fractive index is liable to become great and th refore, where the half wavelength optical phase plate is made common to two colors, the combination of red and green is more desirable.

Figure 7 schematically shows the construction of another embodiment of the present invention. In this embodiment, portions common to those in the previous embodiment are given the same reference numerals. P-polarized light emergent from the polarizing element 31 passes through a polarizing beam splitter 68, whereafter it is resolved into three colors, red, green and blue, by dichroic mirrors 62 and 63, and the three color lights reciprocally travel between half wavel ngth optical phase plates 61R, 61G, 61B and r flection type liquid crystal light valves 67R, 67G, 67B. These r flection type liquid crystal light valves each hav th function of inclining P-polarized light by 45° in conformity with an imag signal and th r for , the P-polarized light is rotated by 90° by reciprocally travelling between th half wav l ngth optical phas plates and th r fl ction typ liquid crystal light valves, and becomes S-polarized light. In this manner, a mixture of the P-polarized light and the S-polarized light is combined by the dichroic mirrors 62 and 63 in conformity with the image signal, and the S-polarized component is reflected by the polarizing beam splitter 68 and is projected onto a screen, not shown, by the projection lens 105. On the other hand, the P-polarized component returns to the polarizing element 31 side. As the reflection type liquid crystal light valves 67R, 67G and 67B, use can be made of liquid crystal of the double refraction modulation type such as 45° TN type liquid crystal, and the half wavelength optical phase plates 61R, 61G and 61B are selected so that the incident polarized light may be one suitable for each liquid crystal system.

Also, in recent years, light valves using ferrodielectric liquid crystal elements have been proposed as liquid crystal light valves.

In an optical modulation element (hereinafter referred to as the "FLC element") using ferrodielectric liquid crystal (hereinafter referred to as "FLC"), a system in which a liquid crystal layer is formed between two plates parallel to each other and having a very small spacing (e.g. 1 - 2 µm) therebetween and a bistable state is created by the use of the surface actions of the two plates (see SSFLC. Appl. Phys. Lett. 36 (1890) 899) is expected to have various applications because of its rapid responsiveness and memorizing property.

The bistable type FLC element exhibits two stable states in a direction in which the axis of liquid crystal molecule differs by a predetermined angle relative to the axial direction (the direction of rubbing or the like) of an orientation acting surface formed as by rubbing on that side of each of the plates sandwiching the liquid crystal layer therebetween which is adjacent to the liquid crystal layer. This angle is called the cone angle (hereinafter represented by θ_c).

When a voltage is applied in a direction perpendicular to the liquid crystal layer surface of the FLC element, the FLC shifts from one stable state to the other stable state. This change corresponds to rotating one major axis of a refractive index elliptical body of a material having refractive index anisotropy by an angle $2\theta_c$ in the liquid crystal layer surface. The axis of liquid crystal molecule and one major axis of the refractive index elliptical body som times do not strictly coincid with each oth r, but y t h re tor simplicity, th two ar regarded as being in the same direction. Accordingly, wh n polarized light ent rs the FLC lement having a thickness corresponding to the action of a half

wav length optical phas plat , th polarizing rotational actions by the tw bistable states to th incid nt polarized light diff r by $4\theta_c$ from ach oth r. If th FLC lem nt is sandwiched between polarizing elements (such as polarizing plates) of cross Nicol or parallel Nicol arrangement, when $4\theta_c = 90°$ ($\theta_c = 22.5°$), the ON-OFF ratio (the transmittance ratio and the contrast) of the quantity of transmitted light in the two bistable states becomes highest.

Now, the cone angle θ_c in the FLC element has considerably great temperature dependency. Therefore, even if the FLC element is disposed so that at a certain temperature, the direction of polarization of incident light and the axis of liquid crystal molecule in one stable state may coincide with each other, at another temperature the direction of polarization of the incident light and the direction of the axis of liquid crystal molecule in one stable state will be deviated from each other by a variation in the cone angle. Accordingly, the incident light will be subjected to the polarizing rotational action and part of the light will be transmitted through an analyzer. Therefore, when the polarizer and the analyzer are disposed in cross Nicol arrangement, a sufficiently dark state cannot be realized and a reduction in contrast will result.

On the other hand, when the polarizer and the analyzer are disposed in parallel Nicol arrangement, a sufficiently bright state cannot be realized and likewise a reduction in contrast will result. An embodiment which can prevent such a reduction in contrast will be shown below.

Referring to Figure 8 which is a partial schematic diagram showing another embodiment of the present invention, there are shown only portions differing from those in the embodiment shown in Figure 5. In this embodiment, portions corresponding to the half wavelength optical phase plate 51R (51G, 51B), the light valve 57R (57G, 57B) and the analyzer 58R (58G, 58B) in Figure 5 are replaced by others. In Figure 8, the reference character 71R designates a half wavelength optical phase plate for rotating the direction of polarization of incident light, the reference character 77R denotes an FLC lement for controlling (modulating) the polarized state of the incident linearly polarized light in conformity with an applied voltage and emitting the light, the reference character 78R designates an analyzer for detecting only a polarized component from the light modulated by the FLC element 77R, and the reference character 72R denotes a signal conversion circuit unit including an ROM memorizing therein a tabl in which th temperatur of liquid crystal is mad in advance to correspond to the angles of rotation of the half wav length optical phase plat 71R and th analyz r 78R. The FLC elem nt 77R comprises transparent substrates 771R and 773R opposed to each oth r, an FLC mol cule layer 772R interposed b tw en th transparent substrat s, and a temp ratur d t cting portion 774R for d tecting th temperature of the FLC molecule layer 772R.

The incident polarized light passed through the half wavelength optical phase plate 71R is modulated by the FLC element 77R, has only its component in the direction of the optical axis of the analyzer 78R transmitted and becomes emergent light. The FLC molecule layer 772R assumes one of two bistable states by changing the magnitude or direction of an electric field applied between transparent electrically conductive layers, not shown, formed on the inner sides of the substrates 771R and 773R.

The temperature information of the FLC molecule layer detected by the temperature detecting portion 774R is passed through the signal conversion circuit unit 72R and becomes a signal for controlling the rotation of the half wavelength optical phase plate 71R and the analyzer 78R.

Figure 9 shows the state of light ray on each layer in the construction of Figure 8 at a certain temperature A [degrees]. Figure 9 shows the state of light ray on each layer in the construction of Figure 8 at a certain temperature B [degrees] ($A \neq B$). The reference numeral 744 in Figure 9 and 10 indicates the orientation acting axis (rubbing direction) of the FLC molecule layer 772R. In these figures, as regards the unit of angle, the clockwise direction with respect to the optical axis will hereinafter be shown as negative.

In Figure 9, polarized incident light E_{in} passes through the half wavelength optical phase plate 71R having its optical axis set so that the direction of polarization of the incident light E_{in} and the direction of the axis of liquid crystal molecule may coincide with each other, whereafter it enters the FLC molecule layer 772R as polarized light having a direction of rotation 745 (the axis of liquid crystal molecule in one of the bistable states) rotated from the orientation acting axis 744 of the FLC molecule layer 772R by the cone angle θ_c at the temperature A [degrees]. If at this time, no electric field is applied to the FLC molecule layer 772R, the polarizing rotational action of the incident light does not take place in the FLC molecule layer 772 and the light rays are all cut by the analyzer and perfect black is expressed. On the other hand, if an electric field is applied to the FLC molecule layer 772R, the axis of liquid crystal molecule in the FLC molecule layer 772R faces a direction 746 and th r for , the incid nt light E_{in}, aft r passed through th FLC molecul lay r 772R having a thickness corresponding to th action of th half wavelength optical phase plat , becomes light having had its direction of polarization rotated by $-4\theta_c$.

The ratio of light passed through the analyz r to light arriving at th analyzer at this time is express d as

$\sin^2(4\theta_c)$.

Next, when the temperature of the FLC molecule layer 772R is B [degrees], as shown in Figure 10, the incident light E_{in} passes through the half wavelength optical phase plate 71R, whereafter in the FLC molecule layer 772R, it enters the FLC l ment 77R as light having a direction of polarization coincident with a direction 745 rotated from the ori ntation acting axis 744 by the cone angle θ_c at th temperature A [degrees]. If at this time, no electric field is applied to the FLC molecule layer 772R, the axis of liquid crystal molecule in one of the bistable states of FLC in the FLC molecule lay r 772R becomes an axis 742, i.e., an axis facing a direction rotated from the orientation acting axis by a cone angle θ_c' at B [degrees], and after the incident light E_{in} has passed through the FLC element 77R, the polarizing rotational action to the polarized light E_{in} becomes $-2(\theta_c - \theta_c')$ on the opposite sides of the axis 742. However, if the half wavelength optical phase plate 71R is rotated by $-\{(\theta_c - \theta_c')/2\}$ from the state of A [degrees] and disposed, the polarized light E_{in} is subjected to a polarizing rotational action by $-(\theta_c - \theta_c')$ and therefor , the direction of polarization of the incident light onto the FLC element 77R coincides with the axis of liquid crystal molecule 742 in one of the bistable states of FLC in the FLC molecule layer 772R. Accordingly, the FLC layer 77R does not cause the polarizing rotational action. At this time, by the analyzer 78R being rotated by $-(\theta_c - \theta_c')$ from the state of A [degrees], the cross Nicol state is kept and the emergent light from the FLC elem nt 77R is all cut in the analyzer 78R, and perfect black is expressed. On the other hand, if an electric fi ld is applied to the FLC molecule layer 772R, the axis of liquid crystal molecule becomes an axis 743, and when the half wavelength optical phase plate 71R is rotated as described above, the rotational action of the polarized light by the FLC molecule layer 772R is $-4\theta_c'$ and further, when the analyze 78R is rotated as described above, the proportion of the transmitted light of the light which has arrived at the analyzer is expressed as $\sin^2(4\theta_c')$.

The element in the signal conversion circuit unit may also be any other functionally similar l ment than the ROM. The temperature detecting portion 774R need not always be attach d to th FLC molecule lay r 772R, but may be attached to the analyzer 78R adjacent thereto.

As described, in th present construction, v n if temperatur changes, perfectly coincid nt black stat s can be reproduced and thus, ther can be provided an element which displays an imag of high contrast and good quality within a wid t mp ratur rang .

Also, in the case of the form shown in Figure 5, the polarizing plate on the incidence side of the liquid crystal light valve is unnecessary in principle, but for the purpose of removing flare light or the like, a polarizing plate having an appropriate transmission axis may be inserted between the polarizing element 31 and the liquid crystal light valve 57R, 57G or 57B. For example, if a polarizing plate is placed between the half wavelength optical phase plate 51 and the liquid crystal light valve 57, the transmission axis of the polarizing plate can be brought into accord with the optical axis of the half wavelength optical phase plate 51, and if a polarizing plate is placed between the half wavelength optical phase plate 51 and the polarizing element 31, the transmission axis of the polarizing plate can be brought into accord with the direction of polarization of the linearly polarized light from the polarizing element 31. Again in these cases, it is desirable that there be a mechanism for adjusting the direction of the transmission axis.

Where use is made of FLC having great temperature dependency like this, linearly polarized light which irradiates the liquid crystal device can be adjusted to a desired direction of polarization correspondingly to any change in temperature.

As described above, in the present invention, linearly polarized light which irradiates a light valve using an element such as TN type liquid crystal whose optical axis on the incident light side differs from the direction of polarization of the linearly polarized light which is incident light can be changed to a desired direction of polarization.

The polarizing element 31 is not limited to that shown in Figure 2, but use can be made of any element which can obtain linearly polarized light or circularly polarized light. For example, where as the polarizing element 31, use is made of an element from which the quarter wavelength optical phase plate 112b in Figure 3 is eliminated and which can obtain circularly polarized light, a quarter wavelength optical phase plate can be employed instead of the aforementioned half wavelength optical phase plate 51 and if the optical axis thereof is set to a desired direction, circularly polarized light can be converted into linearly polarized light in the desired direction of polarization as previously described and the light valve can be irradiated with it.

While the present invention has hitherto been described with respect to a case wh r whit light is resolved into three primary colors, red, green and blue, the present inv ntion can be likewise carried out in a form wh r in whit light is resolved into a gr at r number of colors or two colors.

In th embodim nts shown above, use is mad of liquid crystal light valves, but other light valve syst ms using polariz d light, such as PLZT, ar also ffectiv as m ans for sel cting the direction of polarization of incident light.

Also, in the above-described embodiments, a half wavelength optical phase plate is used to rotate polarized light by 45°, use may also be made of 45° twist nematic liquid crystal or the like.

As described above, according to the present invention, in a projector wherein the polarized states of a plurality of color lights illuminating image forming means differ from the polarized states of image lights projected onto a projection surface and the image lights of respective colors projected onto the projection surface have a common polarized state, means for varying the polarized state is disposed in the optical path of each color light.

Also, according to the present invention, in a projector having image forming means for forming a plurality of color images, illuminating means for illuminating said image forming means with each color light, and projection means for projecting each color image, optical means for turning the direction of polarization by about 45° is disposed in the optical path of said each color light, and this leads to the following effects.

By providing color resolving means, and a polarizing element using an optical phase plate in the optical of each of resolved color lights:

1. Use can be made of linearly polarized light in a direction of polarization matching with the characteristic of the image forming means;
2. A phase plate adapted for each wavelength range can be selected and therefore, it is easy to keep the linear polarizability of polarized light caused to enter the image forming means and accordingly, any reduction in the contrast of image can be prevented;
3. The characteristic of a dichroic mirror as the color resolving means differs considerably depending on the direction of polarization and accordingly, if the direction of polarization is rotated by 45° by a half wavelength optical phase plate before color resolution, the direction of polarization will deviate considerably from 45° depending on the wavelength after the passage through a dichroic mirror, and this causes a reduction in contrast and irregularity of color, whereas the construction of the present invention can prevent this;
4. The direction of polarization of each color light can be independently adjusted in accordance with th charact ristic of each light valv and furth r, th irregularity of th individual difference between the liquid crystal light valves can be coped with, and this adjusting mechanism can be provided on on or both of th optical phas plate and th polarizing plat as th analyzer; and
5. Th optical axis of the optical phase plat can b s t so that corr spondingly to a chang in the temperature of the liquid crystal device such as TN type liquid crystal or FLC, there may be obtained linearly polarized light in a direction of polarization best suited for the direction of orientation axis of the incidence side liquid crystal molecules at said temperature and thus, there can be provided an element which displays images of high contrast and good quality within a wide temperature range, and not only any change in temperature but also any change in humidity or any change in the orientation axis of liquid crystal molecules caused by deterioration with time can be coped with by making the optical axis of the optical phase plate movable.

The present invention can be applied to not only TN type liquid crystal and FLC but also every device that requires linearly polarized light.

In a projector, wherein the polarized states of a plurality of color lights illuminating image forming means differ from the polarized states of image lights projected onto a projection surface and the image lights of respective colors projected onto the projection surface have a common polarized state, means for varying the polarized state is disposed in the optical path of each of the color lights.

Claims

1. A projector having:

   illuminating means emitting first and second color lights differing in color from each other;

   first polarizing means, image forming means and second polarizing means provided in succession from said illuminating means side for said first color light;

   first polarizing means, image forming means and second polarizing means provided in succession from said illuminating means side for said second color light;

   optical means provided in the optical path of at least one of said first and second color lights for changing light in a first direction of polarization into light in a second direction of polarization; and

   means for projecting each image light formed by each of said image forming means, the projected image lights having a common direction of polarization.

2. A projector according to Claim 1, wherein said optical means is a quart r wavel ngth ptical phase plate.

3. A projector according to Claim 1, wh rein said optical m ans is a half wavelength optical phas plat .

4. A projector according to Claim 2 or 3, further having means for detecting any change in the temperature of a member constituting said image forming means and wherein said optical phase plate is rotated about the optical axis thereof in conformity with an output signal from said detecting means.

5. A projector according to Claim 1, wherein each of said image forming means has a twist nematic type liquid crystal valve.

6. A projector according to Claim 1, wherein each of said image forming means has a ferro-dielectric liquid crystal light valve.

7. A projector having:
image forming means for forming first and second images differing in color from each other;
illuminating means for illuminating said image forming means with color lights corresponding to said first and second images;
means for projecting the image lights formed by said image forming means; and
optical means disposed in the optical path of at least one of said color lights for turning the direction of polarization of each of said color lights by about 45°.

8. A projector according to Claim 7, wherein said optical means is a half wavelength optical phase plate.

9. A projector according to Claim 8, further having means for detecting any change in the temperature of a member constituting said image forming means and wherein said optical phase plate is rotated about the optical axis thereof in conformity with an output signal from said detecting means.

10. A projector according to Claim 7, wherein said image forming means has a twist nematic type liquid crystal light valve.

11. A projector according to Claim 7, wherein said image forming means has a ferro-dielectric liquid crystal light valve.

12. A projector having:
illuminating means emitting first, second and third color lights diff ring in color from one anoth r;
first polarizing means, image forming means and second polarizing means provid d in succession from said illuminating m ans sid for said first color light;
first polarizing means, image forming means and second polarizing means provided in succession from said illuminating means side for said second color light;
first polarizing means, image forming means and second polarizing means provided in succession from said illuminating means side for said third color light;
optical means provided in the optical path of at least one of said first, second and third color lights for changing light in a first direction of polarization into light in a second direction of polarization; and
means for projecting the image lights formed by each of said image forming means, the projected image lights having a common direction of polarization.

13. A projector according to Claim 12, wherein said illuminating means has a light source, and color resolving means for resolving the light form said light source into first, second and third color lights differing in color from one another.

14. A projector according to Claim 12, further having color combining means for combining said first, second and third color lights between said image forming means and said projection means.

15. A projector according to Claim 12, wherein said illuminating means has polarizing apparatus having:
means for separating indefinite polarized light into a pair of polarized lights whose directions of polarization are orthogonal to each other;
means for making the directions of polarization of said pair of polarized lights coincident with each other; and
means for making the directions of travel of said pair of polarized lights coincident with each other.

16. A projector according to Claim 12, wherein said illuminating means has polarizing apparatus having:
means for separating indefinite polarized light into a pair of polarized lights whos directions of polarization ar orthogonal to each oth r;
means for conv rting said pair of polarized lights into circularly polarized lights having th

sam direction of rotation; and

means for making th directions of trav l of said pair of polarized lights coincid nt with ach oth r.

17. A projector according to Claim 12, wherein said optical means is a quarter wavelength optical phase plate.

18. A projector according to Claim 12, wherein said optical means is a half wavelength optical phase plate.

19. A projector according to Claim 17 or 18, further having means for detecting any change in the temperature of a member constituting said image forming means and wherein said optical phase plate is rotated about the optical axis thereof in conformity with an output signal from said detecting means.

20. A projector according to Claim 12, wherein said image forming means each have a twist nematic type liquid crystal light valve.

21. A projector according to Claim 12, wherein said image forming means each have a ferro-dielectric liquid crystal light valve.

22. A projector having:

image forming means for forming first, second and third images differing in color from one another;

illuminating means for illuminating said image forming means with color lights corresponding to said first, second and third images;

means for projecting the image lights formed by said image forming means; and

optical means disposed in the optical path of at least one of said color lights for turning the direction of polarization of each of said color lights by about 45°.

23. A projector according to Claim 22, wherein said illuminating means has a light source, and color resolving means for resolving the light from said light source into first, second and third color lights differing in color from one another.

24. A projector according to Claim 22, further having color combining means for combining said first, second and third color lights between said imag forming means and said projection means.

25. A projector according to Claim 22, wher in said illuminating means has polarizing apparatus having:

m ans for separating in d finite polarized light into a pair of polariz d lights whos directions of polarization are orthogonal to each other;

means for making the directions of polarization of said pair of polarized lights coincident with each other; and

means for making the directions of travel of said pair of polarized lights coincident with each other.

26. A projector according to Claim 22, wherein said illuminating means has polarizing apparatus having:

means for separating indefinite polarized light into a pair of polarized lights whose directions of polarization are orthogonal to each other;

means for converting said pair of polarized lights into circularly polarized lights having the same direction of rotation; and

means for making the directions of travel of said pair of polarized lights coincident with each other.

27. A projector according to Claim 22, wherein said optical means is a half wavelength optical phase plate.

28. A projector according to Claim 27, further having means for detecting any change in the temperature of said image forming means and wherein said optical phase plate is rotated about the optical axis thereof in conformity with an output signal from said detecting means.

29. A projector according to Claim 22, wherein said image forming means has a twist nematic type liquid crystal light valve.

30. A projector according to Claim 22, wherein said image forming means has a ferro-dielectric liquid crystal light valve.

31. A projector having:

a light source emitting indefinite polarized light;

polarizing means for converting the light from said light source into polarized light;

color resolving means for resolving the light from said light source into first, second and third color lights diff ring in color from on another;

imag forming means disposed in the ptical path of each of said color lights, said imag forming means controlling the direction

of th optical axis of a m mber having optical anisotropy between different first and second dir ctions to th r by modulat said color lights and form color imag s;

optical means disposed in the optical path of each of said color lights for making the direction of polarization of the polarized light from said polarizing means coincident with the first or second direction of the optical axis of said member; and

projection means for projecting said color images.

32. A pattern producing apparatus having:

pattern forming means for forming first and second patterns differing in color from each other;

illuminating means for illuminating said pattern forming means with color lights corresponding to said first and second patterns, the color lights passed through said pattern forming means having a common direction of polarization; and

optical means disposed in the optical path of at least one of said color lights for changing light in a first direction of polarization into light in a second direction of polarization.

33. A pattern forming method having:

the color light producing step of producing a plurality of lights differing in color from one another;

the pattern forming step of modulating said color lights to thereby form first and second patterns differing in color from each other, the color lights by which said first and second patterns are formed having a common direction of polarization; and

the polarization converting step of converting light in a first direction of polarization into light in a second direction of polarization, said polarization converting step being done by optical means disposed in the optical path of at least one of said color lights.

FIG. 1A

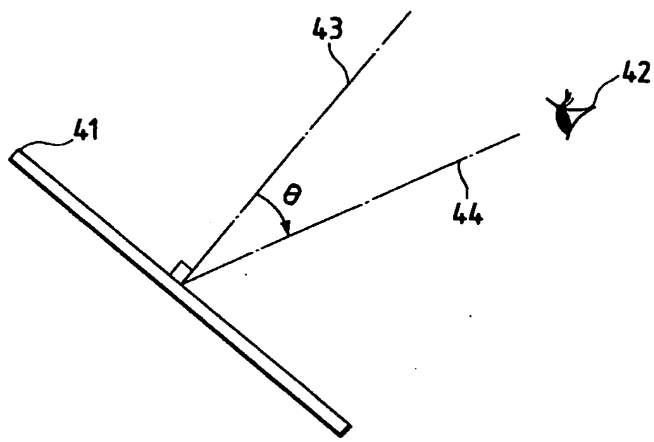


FIG. 1B

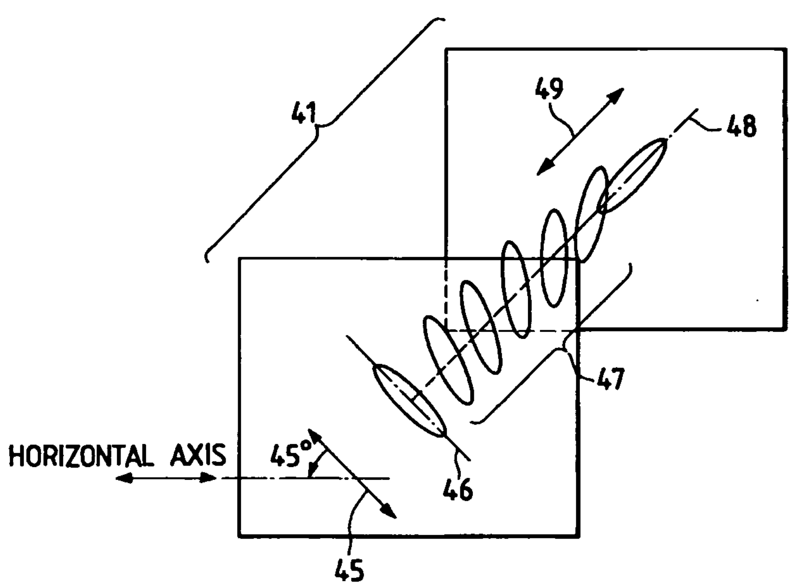


FIG. 2 PRIOR ART

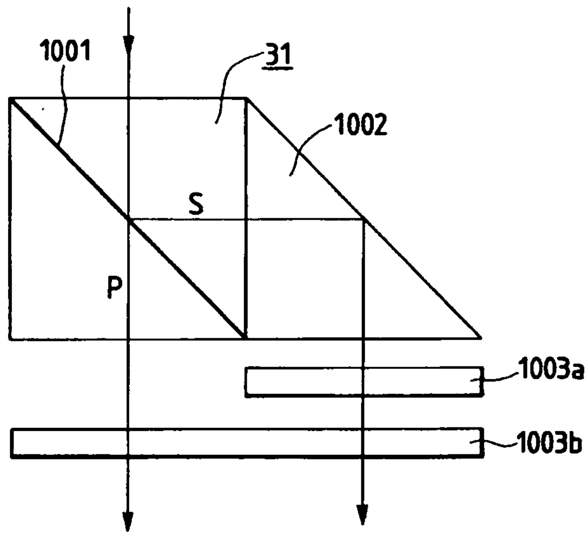


FIG. 3 PRIOR ART

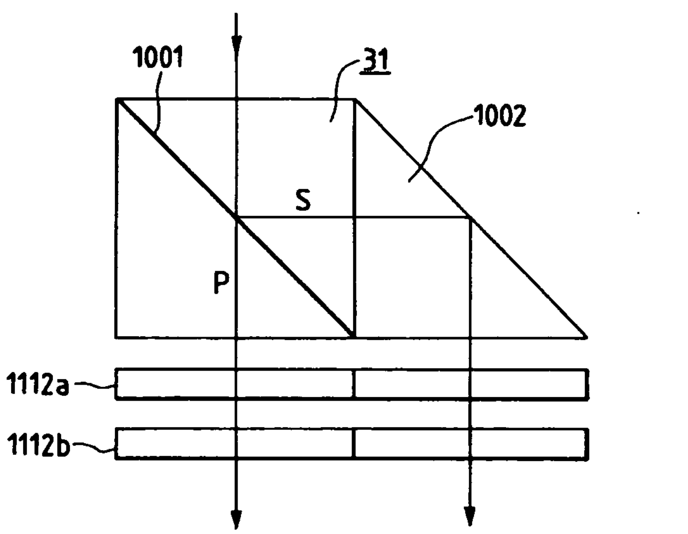


FIG. 4 PRIOR ART

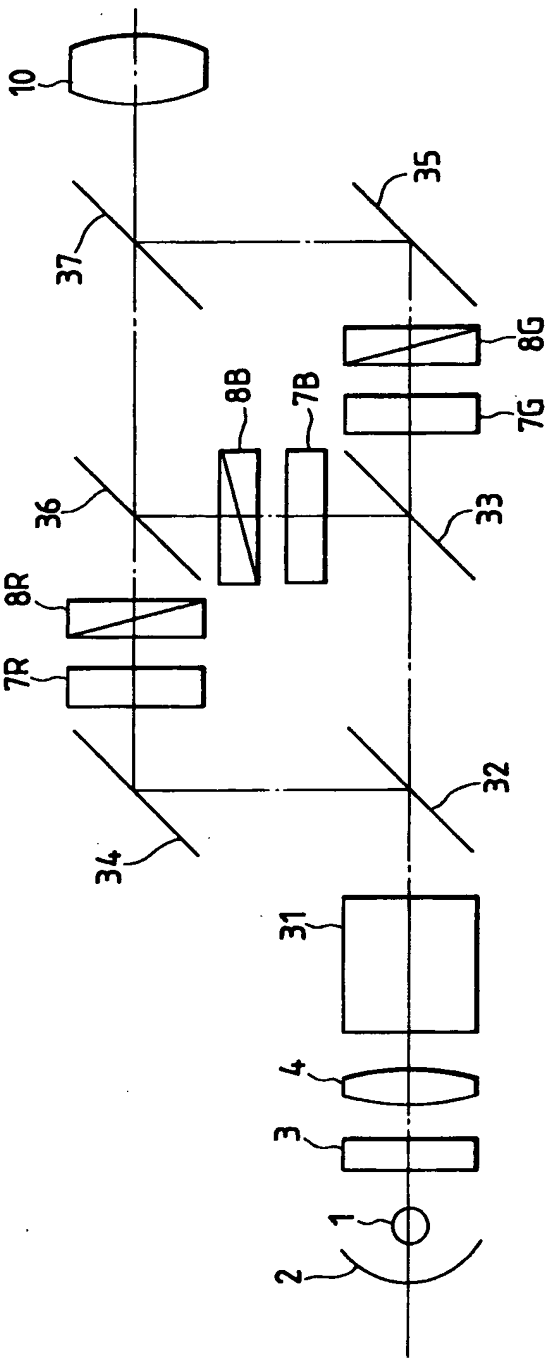


FIG. 5

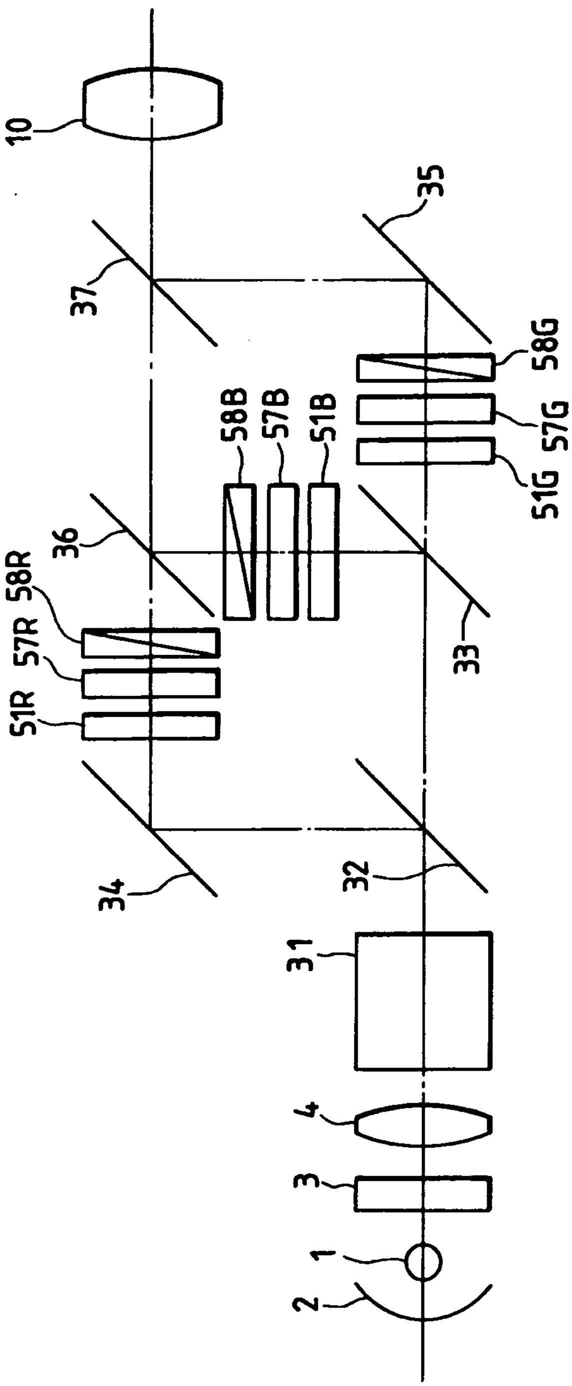


FIG. 6

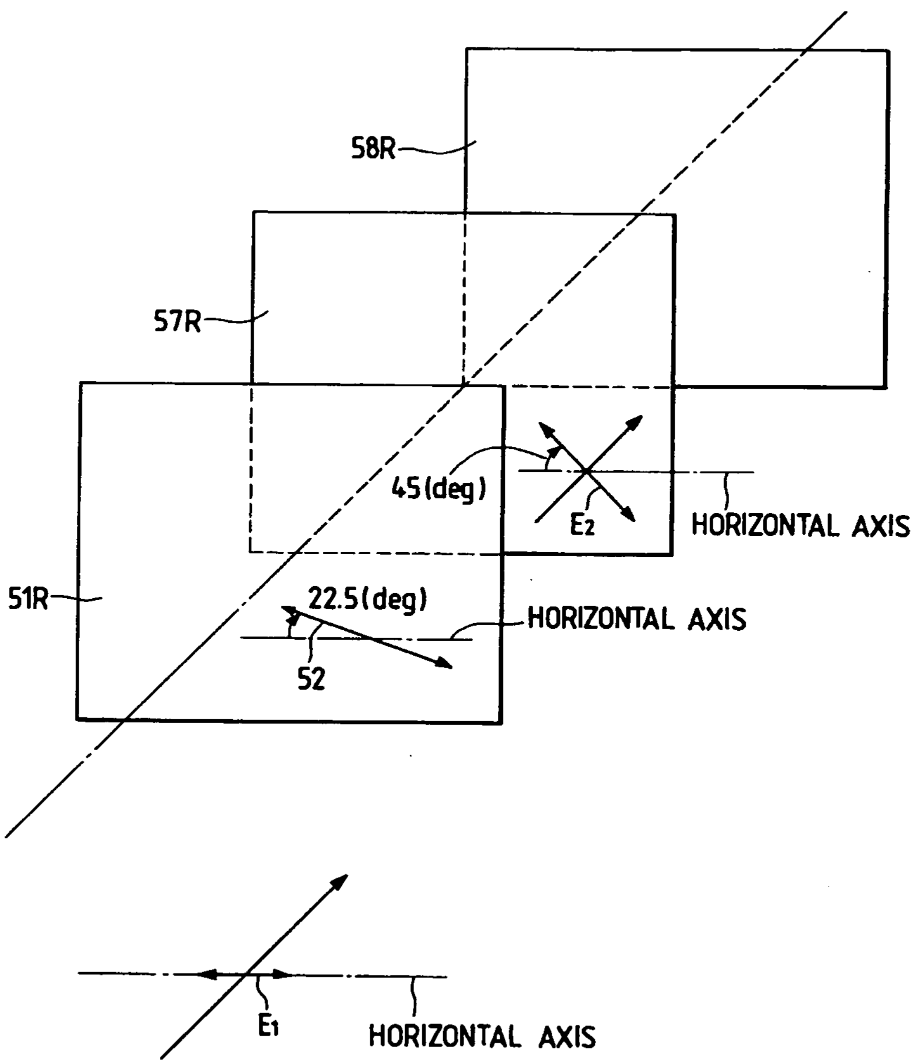

58R
57R
51R
45(deg)
E2
HORIZONTAL AXIS
22.5(deg)
HORIZONTAL AXIS
52
E1
HORIZONTAL AXIS

FIG. 7

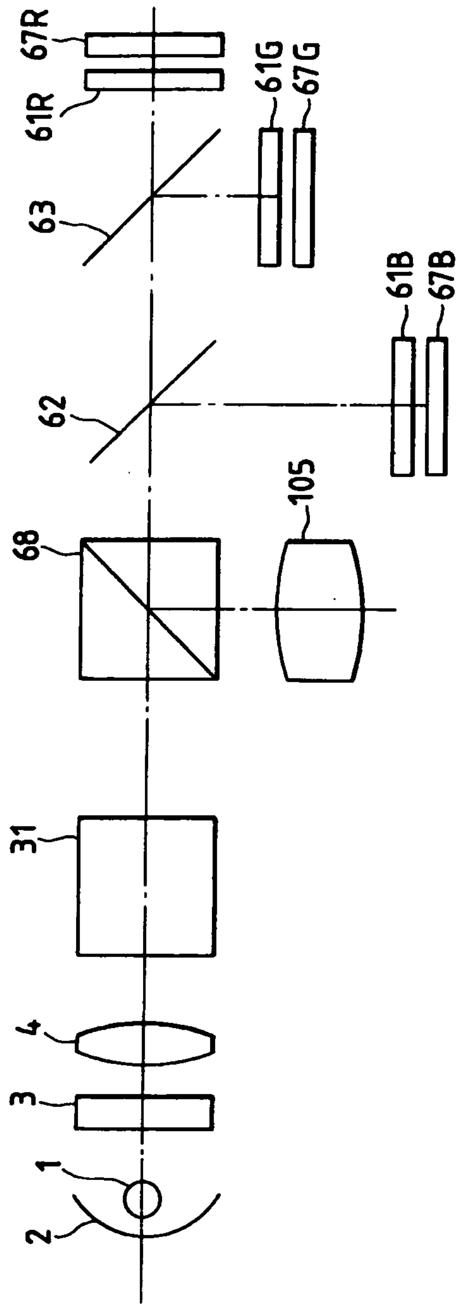


FIG. 8

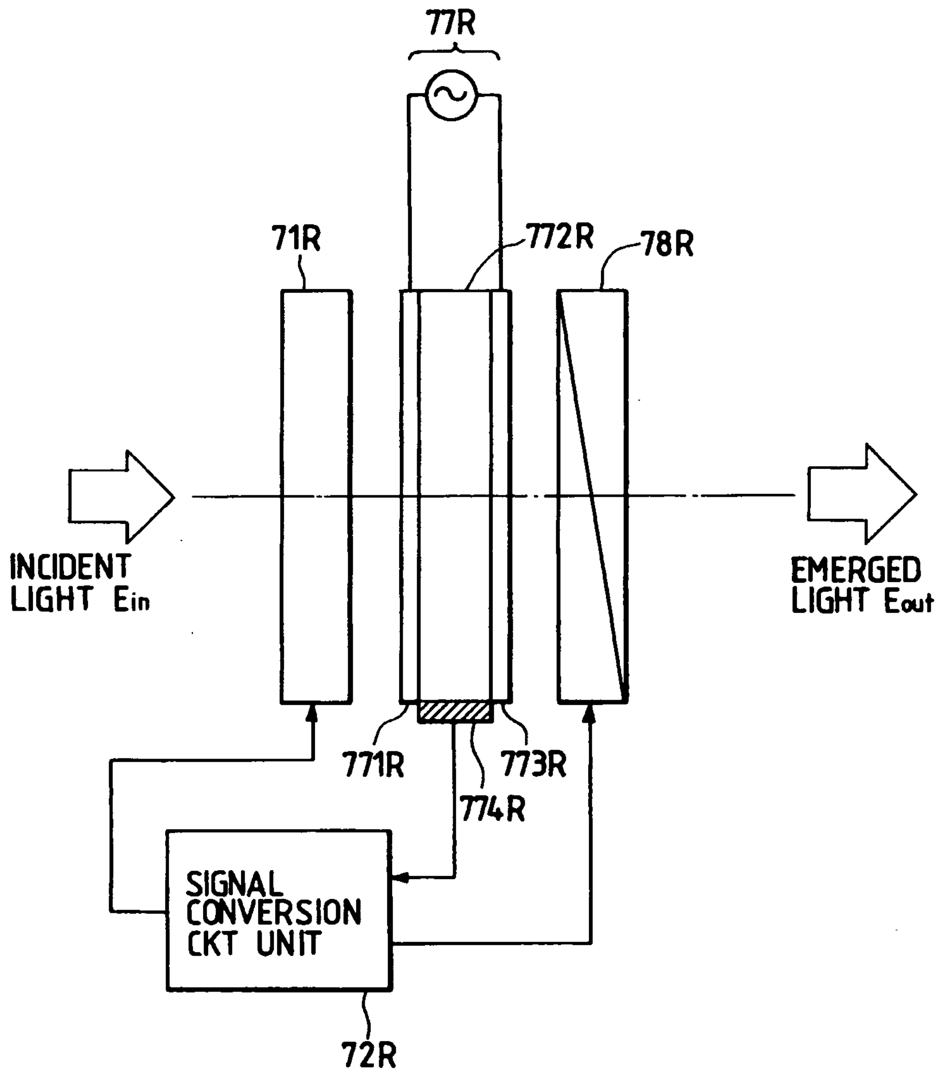

77R
71R
772R
78R
INCIDENT
LIGHT Ein
EMERGED
LIGHT Eout
771R
773R
774R
SIGNAL
CONVERSION
CKT UNIT
72R

FIG. 9

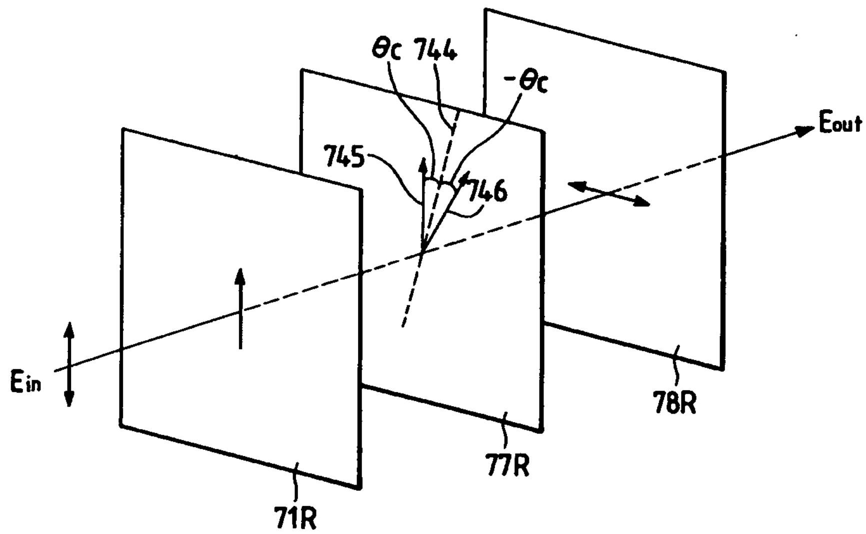
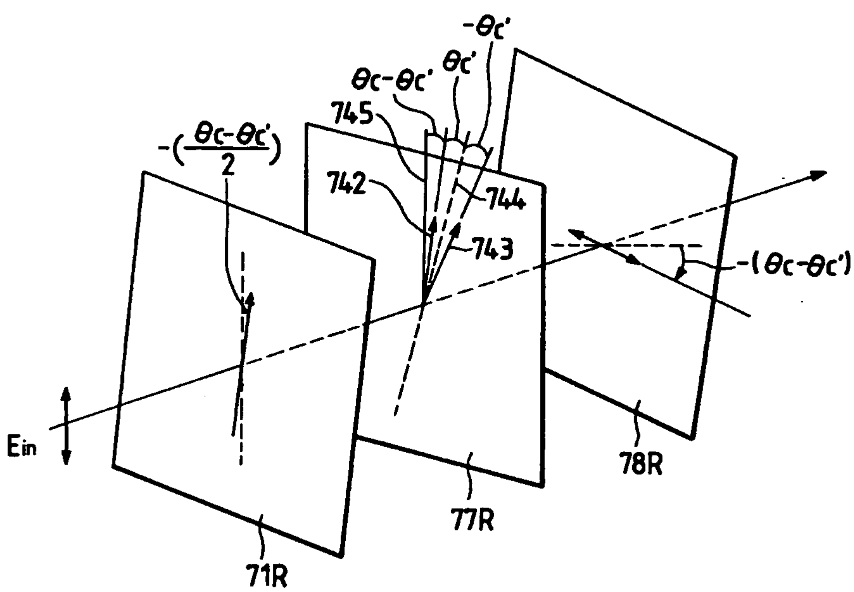

θc 744
-θc
Eout
745
746
Ein
78R
77R
71R

FIG. 10


-θc'
θc'
θc-θc'
745
-((θc-θc')/2)
742
744
743
-(θc-θc')
Ein
78R
77R
71R

European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 92110556.3

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
A	EP - A - 0 311 116 (MATSUSHITA ELECTRIC INDUSTRIAL CO., LTD.) * Column 3, line 29 - column 4, line 32; fig. 1a,1b,7,8 *	1,4,5, 7,9, 10,12, 13,14, 19,20, 22,23, 24,28, 29,31-33	G 02 F 1/13 G 02 B 27/18 H 04 N 9/31
A	US - A - 4 936 658 (TANAKA et al.) * Column 1, line 24 - column 2, line 4; fig. 1-3 *	1,5,7, 10,12-14,20, 22-24, 29,32, 33	
A	WO - A - 88/06 391 (HUGHES AIRCRAFT) * Fig. 1-3 *	1,7, 12-15, 22-25, 31-33	
			TECHNICAL FIELDS SEARCHED (Int. Cl.5)
A	PATENT ABSTRACTS OF JAPAN, unexamined applications, E field, vol. 10, no. 268, September 12, 1986 THE PATENT OFFICE JAPANESE GOVERNMENT page 59 E 436 * Kokai-no. 61-90 584 (SONY CORP.) *	1,3,7, 8,12, 18,22, 27	G 02 B 27/00 G 02 F 1/00 H 04 N 5/00 H 04 N 9/00
D	& JP-A-61-90 584		

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
VIENNA	29-09-1992	GRONAU

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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L : document cited for other reasons

& : member of the same patent family, corresponding document